RESPONSE OF BORON AND SULFUR FERTILIZATION ON MORPHO-PHYSIOLOGICAL, YIELD AND YIELD ATTRIBUTES OF MUSTARD

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CERTIFICATE

This is to certify that thesis entitled, **"RESPONSE OF BORON AND SULFUR FERTILIZATION ON MORPHO-PHYSIOLOGICAL, YIELD AND YIELD ATTRIBUTES OF MUSTARD"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **AGRICULTURAL BOTANY,** embodies the result of a piece of Bonafede research work carried out by **Nusrat Jahan,** Registration **No. 18-09129** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

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DEDICATED TO
MY
BELOVED PARENTS

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ABSTRACT

A field experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Dhaka, during the period from November, 2019 to February, 2020 to study the response of boron and sulfur fertilization on morpho-physiological, yield and yield attributes of mustard. The experiment considered of nine treatment, which are consisted of boron and sulfur *viz*. $T_0 = B_0S_0$, T_1 = 1 Kg B ha^{-1}, T_2 = 2 Kg ha^{-1} B, T_3 = 20Kg ha^{-1} S, T_4 = 40 Kg ha^{-1} S, T_5 = 1 Kg ha^{-1} B + 20 Kg ha^{-1} S, T_6 = 1 Kg ha^{-1} B + 40 Kg ha^{-1} S, T_7 = 2 Kg ha^{-1} B + 20 Kg ha^{-1} S and T_8 = 2 Kg ha^{-1} B + 40 Kg ha^{-1} S. NPK was used in optimum rate in the field (Urea = 350 Kg ha^{-1}, TSP = 220 Kg ha^{-1}, MOP = 100 Kg ha^{-1}). We used Bari Shorisha-14 (*B. campestris)*. The experiment was laid out in a Randomized Complete Block Design with three replications. The data were collected on plant height, number of leaves per plant, number of branch per plant, SPAD value of leaf, silique per plant, seed per silique, 1000 seed weight, seed yield, stover yield, biological yield, harvest index. A statistically significant variation was recorded in terms of all the characters related to growth and yield of mustard. In the experimental findings we found that, the highest plant height at 30, 45 and 60 DAS (52.37, 97.40 and 113.0 cm), maximum leaf number (16.07), highest number of branch per plant (10.07), maximum SPAD value of leaf (52.63), highest number of siliquae (137), maximum number of seeds siliqua^{-1} (34.17), highest weight of 1000 of seeds (3.90 g), highest grain yield (1.64 t ha^{-1}), highest stover yield (3.97 t ha^{-1}), highest biological yield (5.62 t ha^{-1}) and highest harvest index (29.20%) were obtained from the combination of 1 Kg B ha^{-1} + 20 Kg S ha^{-1} (T_5). Therefore, it can be said, that the higher grain yield could be obtained from a combination of 1 Kg ha^{-1} B + 20 Kg ha^{-1} S with NPK.

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LIST OF ABBREVIATION AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
FAO	=	Food and Agricultural Organization
S	=	Sulfur
B	=	Boron
et al.	=	And others
TSP	=	Triple Super Phosphate
MOP	=	Muirate of Potash
RCBD	=	Randomized Complete Block Design
DAT	=	Days after Transplanting
ha	=	Per hectare
g	=	gram (s)
kg	=	Kilogram
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources and Development Institute
Wt	=	Weight
LSD	=	Least Significant Difference
^oC	=	Degree Celsius
NS	=	Not significant
Max	=	Maximum
Min	=	Minimum
%	=	Percent
NPK	=	Nitrogen, Phosphorus and Potassium
CV%	=	Percentage of Coefficient of Variance

Chapter 1

INTRODUCTION

CHAPTER I

INTRODUCTION

Commonly known mustard in Bangladesh, is a cool season, thermo sensitive as well as photosensitive crop (Sharif *et al*. 2016). Mustard (*Brassica* spp.) belongs to the genus Brassica under the family Cruciferae, it has three species that produce edible oil, namely *Brassica napus*. *B. campestris* and *B. juncea*. We used Bari Shorisha-14 (*B. campestris).* Brassica oil crop supplies substantial quality of edible oil in Bangladesh. It accounts for 59.4% of total oil seed production in the country (AIS 2010). In 2013-14, it was cultivated in 724,000 acres, produced 296,000 tons of edible oil seed. In the year 2012-13 and 2014-15 it accounts for 36.61 and 39.84% of total oil seed production in Bangladesh (BBS 2015). In 2019-20, it was cultivated in 764000 acres of land and produced 358000 tons of edible oil seed (BBS 2020). The average per hectare yield of mustard in this country is critically very poor as compared to advanced countries. The average production of rapeseed-mustard is 739 kg ha^{-1} in the country whereas the world average is 1575 kg ha^{-1} (FAO 2011). Therefore, it is necessary to popularize high yielding varieties of mustard with proper fertilizer management for increasing the oil seed production. Justified fertilizers and resource use is crucial to maintain productivity of crops (Sultana *et al*. 2015; Hossain and Siddique, 2015). This crop is ranked as the world's third important oilseed crop. It is an important source of cooking oil in Bangladesh meeting one third of the edible oil requirement of the country (Ahmed, 2008). It is not only a high energy food but also a carrier of fat soluble vitamins (A, D, E and K) in the body. Mustard seed contain 30-45% protein content and 37-49% oil content (Sharma *et al*. 2020).

Fertilizers have effect on yield and yield attributes of crops (Sultana *et al*. 2019). There are 17 essential elements, among them some elements required in comparatively high amounts they are called macronutrients and some in low amounts are called micronutrients. Sulfur (called as macronutrient) and Boron (called as micronutrient) fertilizer are very important for the cultivation of mustard in Bangladesh.

Sulfur plays an important role in various plant growth and development processes being a constituent of sulfur containing amino acids and other metabolites. It is increasingly being recognized as the fourth major plant nutrient after nitrogen, phosphorus and potassium. Sulphur is essential for increasing oil content (%) and oil yield and sulphur application greatly influenced chlorophyll synthesis, carbohydrate as well as protein metabolism and also it is essential for synthesis of amino acids, proteins, oils and activates enzyme system in plant (Sharma *et al*. 2020). Three amino acids *viz*. methionine (21% S), cysteine (26% S) and cystine (27% S) contain sulphur which are the building blocks of proteins. About 90% of sulphur is present in these amino acids (Rehman *et al*., 2013; Sharma *et al*. 2020). Sulphur is also involved in the formation of chlorophyll, glucosides and glucosinolates (mustard oils), activation of enzymes and sulphydryl (SH^-) linkages that are the source of pungency in oilseeds. Sulphur levels significantly influenced the seed and stover yield of mustard (Sharma *et al*. 2020; Sharma *et al*., 2009). Sulfur is related to the synthesis of fatty acids and also increases protein quality through the synthesis of certain amino acids such as cysteine, cysteine and methionine (Havlin *et al.,* (1999). Sulfur also helps for the uptake of nitrogen, phosphorus and potassium (Singh *et al.,* 1988). In general, about 97 percent soils of Bangladesh are lack of sulfur and this deficiency is becoming several, day by day, mainly due to intense crop production coupled with the use of sulfur free fertilizers (Mazid, 1986).

Boron is one of the essential micronutrient required by the plant in very small quantity. The probable roles of boron include sugar transport, cell wall synthesis, lignifications, cell wall structure integrity, carbohydrate metabolism, ribose nucleic acid (RNA) metabolism, respiration, indole acetic acid (IAA) metabolism, phenol metabolism, and as part of the cell membranes (Ahmad *et al.,* 2009).

Brassica sp. is sensitive to low B-supply and severe deficiency may result in floral abortion and significant drop in seed production (Yang *et al*. 1989; Zaman *et al*. 1998). The number of siliquae and seed setting and seed yield of mustard plants is greatly influenced by boron particularly where soil is deficient in boron (Islam and Sarker, 1993; Lei *et al*. 2009). The uptake and requirement of boron differ in different development stages, soil, plant parts, among cultivars and species (Pommerrenig *et al*. 2018). Boron deficiency is the second most intensive micronutrients problem globally (Alloway, 2008). Dubey (1996) reported that major role of Boron in plants is also to maintain the membrane integrity and cell wall development. It also helps the solubility of Calcium as well as mobility of calcium in plants. Boron is necessary for proper pollination and fruit or seed setting, helps in preserving membrane stability of cells, increase ion transport capacity, and is involved in pollen germination (Al-Molla, 1985). Gupta *et al.* (1994) emphasizes the need for a judicial use of B fertilizer. Information to that end is practically meager in our country.

Chatterjee *et al.* (1985) reported that gypsum application at the rate of 20 kg S ha^{-1} in conjugation with borax (10 kg B ha^{-1}) caused 42% increase in seed yield of mustard. Sharma *et al*. (2020) reported that together application of sulphur and boron (45 kg ha^{-1} and 2 kg ha^{-1}, respectively) resulted highest plant height, number of primary and secondary branches, dry matter accumulation, number of siliquae $plant^{-1}$, length of siliqua, number of seeds $siliqua^{-1}$, grain yield ha^{-1}, stover yield ha^{-1} and biological yield ha^{-1} which was also supported by Ma *et al*. (2015).

With a view to determine the boron and sulfur requirement of mustard a field study was conducted with the fallowing objectives:

- To evaluate the response of Mustard by Sulfur and Boron fertilization.
- To study a significant effect of Sulfur and Boron on yield and yield components in Mustard.

Chapter 2

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

The present investigation was conducted to know the response of different treatments of boron and sulphur on crop growth and yield of mustard. This chapter deals review of various experimental finding of different research workers covering important aspects on the effect of boron and sulphur fertilization on morpho-physiological, yield and yield attributes of mustard are presented under following headings:

2.1 Effect of boron

A field experiment was conducted to see the response of mustard crop to B application at Jalapur in Bangaldesh. Application of 1.0 kg B/ha recorded maximum height (105.5 cm) and number of branches/plant (4.43), which was significantly higher than rest of the treatments (0, 0.5, 1.0, 1.5 and 2.0 kg B/ha). It was also observed that application of 1.0 kg B/ha significantly increased siliquae/plant, seeds/siliqua and 1000-seed weight of different mustard varieties than other treatments (0. 0.5, 1.5 and 2.0 kg/ha). However, seed yield which was recorded maximum with 1.0 kg B/ha remained statistically at par with 1.5 kg B/ha (Hussain *et al.,* 2008).

Nadian *et al.* (2010) conducted a field experiment at Mollasani, Iran to study the response of boron on mustard crop and it was found that application of 2.5 kg B/ha registered significantly higher plant height, dry weight and branches as compared to all other treatments *i.e.* 0, 5.0, 7.5 and 10 kg B/ha. Again, the application of 2.5 kg B/ha gave maximum seed yield of canola *(Brassica napus* L.) over the other treatments (0, 5.0, 7.5 and 10 kg B/ha).

Hossain *et al.* (2011) at Jessore in Bangladesh conducted an experiment to study the response of mustard variety BARI sarisha-8 (*B. napus* group) on yield attributes and yield at different levels of B (0, 1.0 and 2.0 kg/ha). It was revealed that application of 1.0 kg B/ha gave maximum values of yield attributes (siliquae/plant, seed/siliqua and 1000-seed weight) and seed yield, which remained at par with application of 2.0 kg/ha. The per cent increase in seed yield was 30-35% over the control (0 kg B/ha).

Rashid *et al.* (2012) conducted an experiment in Bangaldesh to study the response of B application on performance of mustard crop. They found that the application of 1.5 kg B/ha had significant influence on siliquae/plant, seed/siliqua and seed yield over the other treatments (0, 0.5, 1.0 and 2.0 kg/ha). However, 1000-seed weight was not significantly affected with increasing levels of B.

Ansari *et al.* (2013) conducted an experiment to study the efficacy of boron sources on productivity, profitability and energy use efficiency of groundnut and revealed that application of boron through solubor @ 5 kg ha^{-1} significantly increased plant height and grain yield of sesame over different sources of boron like borax, chemibor, agricol, borosol during *kharif* season in New Delhi.

Jeena *et al.* (2013) conducted an experiment at OnattukaraAgro ecological Zone, Kerala revealed that application of 2.5 kg B ha^{-1} reported significantly higher no. of capsules $plant^{-1}$ and seed yield of sesame over control, 5, 7.5 kg B ha^{-1}.

Kabir *et al.* (2013) conducted an experiment and show the effect of phosphorus, calcium and boron on the growth and yield of groundnut and revealed that application of 2.5 kg boron ha^{-1} significantly increased plant height and leaf area index over application of 2.0 kg boron ha^{-1} on silty loam soil of Bangladesh.

Sudeshan and Saren (2013) revealed that significantly increased plant height, dry matter yield and grain yield of winter niger with application of boron as 2% borax spray at branching and it was on par with application of 0.2% borax spray at branching and flowering during *kharif* season in West Bengal.

Gowthami and Rao (2014) revealed that significant increase in leaf area index crop growth rate and relative growth rate was observed with application of boron @ 50 ppm as foliar spray of soybean on clay loam soils in Andhra Pradesh.

The results of the experiment conducted by Tahir *et al.* (2014) with different levels of boron *i.e.* 2, 4, 6, 8, 10 kg B ha^{-1} recorded an increasing trend in plant height upto 6 kg B ha^{-1} beyond that plant height have shown deceasing trend. Application of 6 kg B ha^{-1} recorded significantly higher plant height of sunflower on sandy loam soils during *spring* season in Pakistan.

Naiknaware *et al.* (2015) reported that four levels of boron viz., no boron (B0), 4 kg B ha^{1} (B1), 8 kg B ha^{1} (B2) and 12 kg B ha^{-1} (B3) and three levels of elemental sulphur viz., no sulphur (S0), 20 kg S ha^{-1} (S1) and 40 kg S ha^{-1} (S2). The results of the experiment revealed that the groundnut crop fertilized with 8 kg boron showed remarkably increased plant growth parameters viz., No. of pegs per plant (43.88) and No. of nodules (102.00) at 50-55 DAS and yield attributes viz., numbers of pods per plant (10.83) and kernel yield (1214 kg ha^{-1}).

Yadav *et al.*, (2016) conducted a field experiment to study the effect of boron (B) on growth, yield and quality of mustard (*Brassica juncea* L.). The experiment comprised of 11 B levels i.e., 0, 0.5, 1.0, 1.25, 1.5, 1.75, 2.0, 2.25, 2.50, 2.75 and 3.0 kg B ha^{-1}. The results revealed that the highest number of siliqua $plant^{-1}$ (242 and 245), length of siliqua (5.3 and 5.4 cm), number of seeds $siliqua^{-1}$ (16.3 and 16.2), seed yield (1.89 and 2.02 t ha^{-1}), oil content (35.5 and 36%) were recorded where 1.5 kg B ha^{-1} was applied, while maximum protein content (22.2 and 21.9%) was noticed with application of 1.75 kg B ha^{-1} during 2012-13 and 2013-14, respectively. Application of 1.5 kg B ha^{-1} gave average increase in seed yield of 36% and oil yield of 52%. It also increased the uptake of B by seed and stover significantly over control.

Yadav *et al.* (2016) conducted an experiment on Indian mustard with different levels of B (0, 0.5, 1.0, 1.25, 1.5, 1.75, 2.0, 2.25, 2.50, 2.75 and 3.0 kg B/ha). They reported that plant height remained unaffected with increasing levels of B. However, primary and secondary branches/plant were significantly increased and maximum number of branches was recorded with RDF (N: P_2O_5: K_2O: S: Zn - 90: 60: 40: 40: 5 kg/ha) +1.5 kg B/ha. It was also reported that application of 1.5 kg B/ha have maximum siliquae/plant (242 and 245), number of seeds/siliqua (16.3 and 16.2) and seed yield (1.89 and 2.02 t/ha) during both years.

Kour *et al.* (2017) conducted an experiment and reported that maximum value of plant height and primary branches increased significantly with recommended dose of fertilser (RDF) + 10 kg Zn + 2 kg B/ha, which was at par with RDF + 10 kg Zn + 1 kg B/ha and RDF + 5 kg Zn + 2 kg B/ha. However, response of RDF + 10 kg Zn + 2 kg B/ha was significantly higher than control (RDF @ 60: 30: 15: 20 kg/ha NPKS). Application of RDF (60: 30: 15: 20 kg/ha NPKS) + 10 kg Zn + 2 kg B/ha in mustard crop also obtained maximum seed yield (1.25 t/ha). The seed yield obtained under this treatment was 22.3% higher than RDF.

Riaj and Hussain (2018) conducted a field experiment to find out the effect of nitrogen and boron on the yield and yield attributes of mustard. The experiment consisted of two factors. Factor-A: nitrogen (N) doses: 4 doses, N_0= without nitrogen, N_1= 60 kg ha^{-1}, N_2=90 kg ha^{-1}, N_3=120 kg ha^{-1} and factor-B: boron (B) doses: 3 doses, B_0= without boron, B_1=1 kg ha^{-1}, B_2= 2 kg ha^{-1}. Data on different parameters related to seed yield and quality was recorded and statistically significant variation was found for nitrogen and boron. In terms of nitrogen fertilizer, 120 kg N ha^{-1} produced the highest in respect of plant height (67.67 cm), number of branches per plant (6.94), number of siliqua per plant (151.44), number of seeds per siliqua (24.90), 1000 seed weight (3.81 g), seed yield (1466.33 kg ha^{-1}), stover yield (4577.96 kg ha^{-1}), harvest index (24.23 %) and the lowest value found at control in most of the parameters. In case of boron fertilizer, plant height

(59.75 cm), number of branches per plant (6.67), number of siliqua per plant (124.61), number of seeds per siliqua (22.51), 1000 seed weight (3.71 g), seed yield (1321.08 kg ha^{-1}), stover yield (4378.55 kg ha^{-1}), harvest index (22.97%) were highest in boron @ 2 kg B/ha whereas the lowest results were found in control. Due to the interaction effect of nitrogen and boron in mustard, the plant height (72.00 cm) , number of branches per plant (7.39), number of siliqua per plant (157.00), number of seeds per siliqua (26.37), 1000 seed weight (3.86 g), seed yield (1569.00 kg ha^{-1}), stover yield (4712.65 kg ha^{-1}), harvest index (25.00%) were highest in nitrogen @ 120 kg N ha^{-1} combined with boron @ 2 kg B ha^{-1} whereas the lowest value was found in nitrogen @ 0 kg N ha^{-1} combined with boron @ 0 kg B ha^{-1} in mustard.

Nadaf and Chandranath (2019) conducted a field experiment to study the effect of zinc and boron levels on yield, quality and nutrient uptake in mustard with 10 treatments. The treatment comprised of two levels of zinc (10 kg ha^{-1} and 20 kg ha^{-1}) and two levels of boron (1 kg ha^{-1} and 2 kg ha^{-1}) and their combinations. These treatments were compared with RDF + FYM @ 5 t ha^{-1} and RDF (60:50:40 N: P_2O_5: K_2O) alone. The treatments were replicated thrice in a randomized block design. The experimental soil being deficient in zinc and boron, good response of crop to the applied zinc and boron was noticed. Application of $ZnSO_4$ @ 20 kg ha^{-1} along with borax @ 2 kg ha^{-1} recorded higher seed yield (1973 kg ha^{-1}), oil content (37.08 %), oil yield (731 kg ha^{-1}), uptake of zinc (242 g ha^{-1}) and boron (76 g ha^{-1}) were noticed over RDF + FYM alone. However which was on par with application of RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 1 kg ha^{-1} and RDF + $ZnSO_4$ @ 10 kg ha^{-1} + Borax @ 2 kg ha^{-1}.

Masum *et al.*, (2019) conducted a study to quantify the effect of boron on yield and yield attributes of mustard (BARI Sarisha-14), and different doses and form of B application. Five B (boric acid) levels *viz.* T_1 = basal application of B @ 2kg ha^{-1}; T_2 = foliar spray (FS) of B @ 0.5% at vegetative stage (VS); T_3 = FS of B @

1% at VS; T_4 = FS of B @ 0.5% at VS + pod formation stage (PFS) and T_5 = FS of B @ 1% at VS + PFS and T_6 = control (no boron) were used. Results indicated that yield and yield attributes of mustard were significantly influenced by boron application. The effects of boron were significant on number of siliquae plant^{-1}, number of seeds siliqua^{-1}, seed yield, stover yield, 1000-seed weight, biological yield and harvest index (%). The highest number of siliquae plant^{-1} (35.93), number of seeds siliqua^{-1} (30.03), stover yield (1946.0 kg ha^{-1}) and 1000-seed weight (3.617 g) were obtained from the treatment T_5. The seed yield (801.17 kg ha^{-1}) was found also in the treatment T5 which was over double than control (T_6). Therefore, two times foliar application of B @1% at VS and PFS is a good option to increase yield and yield contributing characters of BARI Sarisha-14 in AEZ 20.

2.2 Effect of sulphur

Kanpara *et al.* (1992) performed that the growth character of mustard such as plant height was significantly increased up to 100 kg S ha^{-1}.

Mustard seed yield increased by 9, 16 and 23% over the control (no S application), respectively with the application of 15, 30 and 45 kg S/ha (Piri and Sharma, 2007).

The seed yield of different *Brassica* oilseed species/cultivars increased with increasing levels of sulphur up to 30 kg/ha (Malhi *et al.*, 2007). The increment in seed yield per 10 kg S application from 0 to 40 kg/ka was found maximum with single dose of S application (1181 kg/ha). However, the incremental response reduced with the application of second dose from 10 to 20 kg S/ha (417 kg/ha), third dose from 20 to 30 kg S/ha (179 kg/ha) and lowest increment was with 30 to 40 kg S/ha (-34 kg/ha).

Kumar *et al.* (2009) conducted an experiment at BHU in Varanasi and they reported that increasing rates of S up to 45 kg/ha had significant effect on yield attributes and yield. The maximum number of siliquae/plant (330), seeds/siliqua (15.4), 1000-seed weight (4.68 g), seed (1.25 t/ha) and straw yield (4.20 t/ha) was obtained with 45 kg S/ha, which was 20.4, 7.5, 4.6, 16.4 and 9.5 % higher than control, respectively.

Singh *et al.* (2010) conducted an experiment at Banaras Hindu University, Varanasi and reported that siliquae/plant and seeds/siliqua increased significantly with application of 60 kg S/ha. However, significant increment in 1000-seed weight, seed yield and stover yield was noticed up to 30 kg S/ha. The seed yield (1.90 t/ha) was highest with the application of 60 kg S/ha. The per cent increase in seed yield with 60 kg S/ha was 15.5 and 19.7 per cent than 30 kg S/ha and control (0 kg S/ha).

Application of 40 kg S/ha at Allahabad, Uttar Pradesh recorded the highest seed yield (1.93 t/ha) of mustard crop followed by 1.89 t/ha, 1.83 t/ha and 1.63 t/ha with the application of 60 kg S/ha, 20 kg S/ha and 0 kg S/ha, respectively (Yadav *et al.,* 2010).

Kapur *et al.* (2010) conducted an experiment and reported that plant height, primary and secondary branches increased significantly with application of 60 kg S/ha, while primary and secondary branches remained statistically at par with 45 kg S/ha and 30 kg S/ha. Seed yield (1.81 t/ha) of mustard crop was also maximum with 60 kg S/ha, which was at par with 45 kg S/ha and 30 kg S/ha. The seed yield increased with the application of 60 kg S/ha, which was 45 %, higher over the control.

Kumar *et al.* (2011) conducted an experiment and revealed that the application of sulphur @ 45 kg/ha produced maximum plant height and branches/plant, which was statistically at par with 30 kg S/ha, but both were significantly higher than other treatments *i.e.* 0 and 15 kg S/ha. Application of 45 kg S/ha also produced highest seed and stover yield, which were at par with 30 kg S/ha and significantly higher over 15 kg S/ha and control.

A field experiment was conducted at IARI, New Delhi by Piri *et al.* (2011) was reported that dry matter accumulation increased significantly with application of 45 kg S/ha as compared to control at 45, 90 DAS and at harvest.

Begum and Hossain (2012) conducted field experiments at BARI, Joydebpur, Gazipur during the period from November to February in 2004-05 and 2005-06 to evaluate the effect of different levels of sulphur (0, 20, 40, 60, and 80 kg/ha) on rapeseed variety BARI Sarisha-15. Results showed that the most of the growth parameters and yield attributes were significantly influenced by different doses of sulphur. The growth parameters, yield and yield contributing characters were increased with the increasing levels of sulphur fertilizer up to 60 kg S/ha and with the doses beyond that were found to decrease. All growth parameters like plant height, leaf area, dry matter accumulation, leaf area index, crop growth rate, net assimilation rate, and relative growth rate and all yield components, such as number of siliquae per plant, seeds per siliqua, 1000-seed weight and seed yield per plant were found maximum from the treatment with 60 kg S/ha, which was at par with 80 kg S/ha. The highest seed yield (1990 and 1896 kg/ha) were found when S was used @ 60 kg/ha. The same treatment gave 24.71 % and 24.32 % higher seed yield than the control treatment, which were statistically identical with dose at 80 kg /ha of sulphur in both the years.

Dash *et al.* (2012) conducted an experiment in West Bengal in a typical lateritic soil (alfisol) and reported that ‘chlorophyll-a’ content in mustard leaves was significantly higher with application of 60 kg S/ha at 30 and 60 DAS.

The increasing levels of sulphur significantly increased chlorophyll content (a, b and total) of mustard leaves and highest chlorophyll content (a - 0.8%, b - 1.13% and total - 1.94 %) was recorded with 45 kg S/ha (Parmar and Parmar, 2012).

Jat *et al.* (2012) studied the response of mustard to varying levels of S (0, 20, 40, 60 and 80 kg S/ha) and Zn (0, 2.5, 5, 7.5 and 10 kg Zn/ha) on growth, yield attributes and seed yield. The varying levels of S and Zn have significant influence on chlorophyll content of mustard up to 40 kg S/ha and 5 kg Zn/ha, however chlorophyll content was recorded maximum with 80 kg S/ha and 7.5 kg Zn/ha. They also found that application of S @ 40 kg/ha and Zn @ 5 kg/ha had significant influence on yield attributes and seed yield over the rest of treatments.

Pachauri *et al.* (2012) conducted an experiment at Agra and reported that dry weight/plant was significantly higher under the application of 60 kg S/ha than control (0 kg S/ha) and 40 kg S/ha.

Dubey *et al.* (2013) conducted an experiment at Faizabad in Uttar Pradesh and studied the responses of various levels of S and Zn on mustard growth and yield parameter and reported that plant height was recorded maximum with 60 kg S/ha at 30 and 60 DAS. However, dry matter accumulation at 30, 60, and 90 DAS significantly increased up to 40 kg S/ha + 7.5 kg Zn/ha. Application of 40 kg S/ha had also significantly higher seed and stover yield. Similarly, application of 7.5 kg Zn/ha also produced maximum seed and stover yield. However, harvest index increased significantly up to application of 40 kg S/ha but it was not significantly affected with varying level of Zn application.

Singh *et al.* (2013) reported that mustard seed yield increased significantly up to 40 kg S/ha along with 6 kg Zn/ha. The maximum seed and stover yields were recorded with application of 60 kg S/ha and 9 kg Zn/ha, which was at par with 40 kg S/ha and 6 kg Zn/ha, respectively.

Sah *et al.* (2013) conducted an experiment and reported that application of sulphur significantly increased plant height up to 15 kg S/ha and further increase in S level did not affect the plant height. However, application of S up to 45 kg/ha, significantly increased the primary and secondary branches as well as the dry matter production. It was also reported that the yield attributes namely number of siliquae/plant, seed/siliqua, 1000-seed weight, seed yield (1.92 t/ha) and stover yield (3.62 t/ha) were recorded significantly higher with 45 kg S/ha.

The seed yield and stover yield of mustard were increased linearly up to 60 kg S/ha but significant increment in seed yield was noticed up to 30 kg S/ha at Jammu (Kour *et al.,* 2014).

Ray *et al.* (2015) in West Bengal, reported that seed and stover yield were recorded highest with 60 kg S/ha, the per cent increment in seed and stover yield were 17.9% and 18.2% over the control (0 kg S/ha), respectively.

A field experiment conducted at Chitrakoot in Bundelhand region and it was observed that the application of S up to 40 kg/ha resulted in significant increase in seed yield. Application of 50 kg S/ha, 40 kg S/ha and 30 kg/ha increased seed yield by 17.96%, 20.76% and 13.64% over the control (0 kg S/ha), respectively (Singh *et al.,* 2016).

Singh and Pandey (2017) reported that application of 45 kg S/ha + 5 kg Zn/ha at Gwalior, Madhya Pradesh showed maximum increase in plant height and branches/plant, which was statistically similar with 30 kg S/ha + 2.5 kg Zn/ha while significantly higher than control (0 kg S/ha+ 0 kg Zn/ha).

At Dantiwada, it was reported that higher seed and stover yield were obtained with application of 60 kg S/ha, which was statistically similar with 40 kg S/ha while significantly higher than 20 kg S/ha and control (Sipiai *et al.,* 2017). However, maximum seed and stover yields were recorded with 5 kg Zn/ha, which 13.9% higher over 2.5 kg Zn/ha and 34.1% higher over 0 kg Zn/ha.

Negi *et al.* (2017) carried out a field experiment during *rabi* season at Pantnagar, to evaluate the effect of either zypmite or gypsum for sulphur on the mustard crop. There were three levels of sulphur (20, 40 and 60 kg S ha^{-1}) along with a control (no sulphur). It was reported that significant increase in the number of branches plant^{-1}, number of siliqua plant^{-1}, 1000-seed weight and straw yield over control were obtained by 60 kg S ha^{-1}.

Varenyiova *et al.,* (2017) carried out an experiment to assess sulphur nutrition and its effect on yield and oil content of oilseed rape *(Brassica napus* L.) within the agricultural cooperative in Mojmirovce during 2013-14. The result revealed that maximum yield of 3.96 t ha^{-1} was obtained with application of 40 kg ha^{-1} S and highest average oil production of 1809 kg ha^{-1} was found when 15 kg ha^{-1} S was applied.

Singh *et al.* (2017a) conducted an experiment at Banaras Hindu University, Varanasi and they observed that plant height, primary and secondary branches/plantas well as dry matter/plant increased significantly with increasing levels of S up to 40 kg/ha. Application 40 kg S/ha also significantly enhanced siliquae/plant, seeds/siliqua, 1000-seed weight, seed yield and stover yield than control, 20 and 30 kg S/ha. Similarly, the maximum value of these attributes were recorded with 40 kg S/ha (Chaurasiya *et al.,* 2018).

The growth parameters namely plant height, branches/plant and dry matter production increased significantly up to 30 kg S/ha, while maximum values of these parameters were recorded with 60 kg S/ha (Kumar *et al.,* 2018).

Kumar *et al*. (2018) studied the response of three *Brassica juncea* varieties (Maya, Giriraj, NRCHB 506) at three levels of S (0, 30 and 60 kg/ha) supplied by two varying sources (elemental S and bentonite S) at Varanasi, Uttar Pradesh. They reported that siliquae/plant, seeds/siliqua and seed yield were maximum obtained with the application of 60 kg S/ha. The seed and stover yield were 8.20 and 7.92 per cent higher under 60 kg S/ha than control, respectively.

Meena *et al.,* (2018) carried out a field experiment during 2016- 2017 to assess the effect of biofertilizers and levels of sulphur on growth and yield of mustard *[Brassica juncea* (L.) Czern. & Coss]. They observed that growth parameters like plant height (167.50 cm), dry weight (44.40 g), number of branch plant^{-1}(6.80) and yield attributes such as number of siliqua plant^{-1} (291.20) and test weight (4.51 g) were recorded at its maximum in the treatment T_{12} with the application of Azotobacter + Phosphate Solubilizing bacteria + 40 kg S ha^{-1} over the control.

Nath *et al.,* (2018) conducted a field experiment in eastern Uttar Pradesh at the farm of Krishi Vigyan Kendra during 2014-15 and 2015-16 to assess the effect of sulphur fertilization on yield, sulphur uptake and oil content in Indian mustard under sandy loam soil. They found that dual application of basal along with sulphur 80% WP 1.25 kg ha^{-1} foliar sprayed at 75 DAS had significant influence on yield attributes, grain yield, sulphur uptake and oil per cent in mustard. The highest average value of the parameters recorded are plant height (158.75 cm), seed siliqua^{-1} (13.45), test weight (4.863 g), grain yield (21.86 q ha^{-1}) and oil content (33.73%).

The maximum seed yield was obtained with application of 60 kg S/ha, which remained statistically similar with 40 kg S/ha and significantly higher than 20 kg S/ha and control (0 kg S/ha) at Faizabad Uttar Pradesh (Rajput *et al.,* 2018).

Rana *et al.* (2018) studied the response of mustard to varying levels of S (0, 15, 30, 45 and 60 kg S/ha) and Zn (0, 2.5, 5.0 and 7.5) on nutrient uptake and seed yield at Rajuala Research Farm, Chitrakoot in Bundelkhand region. They revealed that maximum seed and stover yields were obtained with the combined application of 45 kg S/ha and 5 kg Zn/ha.

An experiment was conducted at JNKVV, Jabalpur by Sharma *et al.* (2018) to study the response of S on mustard crop. They reported that application of 60 kg S/ha obtained maximum seed yield (1.78 t/ha). The seed yield increased by 47.1% with the application of 60 kg S/ha than control (0 kg S/ha).

The seed yield/ha, biological yield/ha and harvest index of mustard crop increased significantly with the application of 45 kg S/ha than 30 kg S/ha, 15 kg S/ha and control at Jhansi, Uttar Pradesh (Singh and Singh, 2018).

Kumar *et al.* (2019) reported that highest mustard seed yield was obtained with the application of 40 kg S/ha, which was significantly superior to 20 kg S/ha and control (0 kg S/ha).

Rammeh *et al.* (2019) studied the response of rapeseed *(Brassica napus* L.) variety (Hyota 401) to varying levels of sulphur (0, 12, 24 and 36 kg S/ha) in terms of yield attributes and yield. They revealed that seed yield/ha of rapeseed crop increased significantly with increasing rate of S application from 0 to 36 kg S/ha. The per cent of increase in seed yield under 36 kg S/ha was 17% than control (0 kg S/ha).

An experiment was conducted at Varanasi by Rana *et al.* (2019) and they reported siliquae/plant, seeds/siliqua and 1000-seed weight were recorded maximum with the application of 60 kg S/ha, but the difference between 30 and 60 kg S/ha was non-significant.

Rana *et al*. (2020) conducted a field experiment during the winter season to study the effect of sulphur fertilization and irrigation scheduling on mustard hybrids at Varanasi, India. There were three levels of sulphur (0, 30 and 60 kg S ha^{-1}) results revealed that the application of sulphur 60 kg S ha^{-1} gave maximum plant height, no. of primary, no, of secondary branches and dry matter accumulation.

A field experiment was conducted by Sultana et al., (2020) at Mymensingh to study the effect of sulphur and zinc nutrition to the seed yield and oil content of mustard during *rabi* season and observed that the number of branches $plant^{-1}$ (5.33), siliqua $plant^{-1}$ (261.8), seeds $siliqua^{-1}$ (17.58), 1000-seed weight (3.03 g), seed yield (1160 kg ha^{-1}), amount of oil content (39.35%) and stover yield (2535 kg ha^{-1}) was found maximum at the application of 60 kg S ha^{-1}.

2.3 Effect of boron and sulphur fertilizer combination

Karthikeyan and Shukla (2011) studied the effect of combined of Boron and Sulphur on nutrient uptake and quality parameters of mustard (*Brassica jiawea* L.) and sunflower (*Helianthus annuus* L.).Significant combined effect of Boron and Sulphur on dry matter and seed yields of both crops was observed. They also revealed that combined of Sulphur (60mg kg^{-1}) and Boron (2mg kg^{-1}) influenced significantly the oil and protein content of mustard and sunflower.

Devi *et al.* (2012) studied the effect of sulphur and boron fertilization on yield, quality and nutrient uptake by soybean under upland condition. The experiment comprises five levels of sulphur (0, 10, 20, 30 and 40 kg sulphur per hectare) and five levels of boron (0, 0.5, 1.0, 1.5 and 2.0 kg boron per hectare). The overall result revealed that application of 30 kg sulphur per12 hectare and 1.5 kg boron per hectare were found to be the optimum levels of sulphur and boron for obtaining maximum yield, oil and protein content, total uptake of sulphur and boron.

Singh *et al.* (2012) studied the effect of sulphur and boron fertilization on yield attributes and yield of soybean. There were 25 treatment combinations consisting of five rates of both S (0, 10, 20, 30 and 40 kg S/ha) 14 and B (0, 0.5, 1.0, 2.0 and 4.0 kg B/ha). The results of the experiments revealed that application of 30 kg S/ha recorded better yield attributes viz., branches/plant, pods/plant, seeds/pod and 100-seed weight and higher yield than the other treatments. Similarly, application of boron at 1.0 kg/ha recorded better yield attributes and higher yield of grain and straw.

Ma *et al.*, (2015) conducted field experiments were to investigate the growth, yield, and yield components of canola in response to various combinations of preplant and sidedress nitrogen (N) with soil-applied sulfur (S) and soil and foliar-applied boron (B). Canola yield and all its yield components were strongly correlated (r2 = 0.99) with the amount of N applied, as was the above-ground biomass at 20% flowering and the leaf area index. Sidedress N was more efficiently utilized by the crop, leading to greater yields than preplant N application. On average, canola yields increased by 9.7 kg ha^{-1} for preplant N application and by 13.7 kg ha^{-1} for sidedress N application, for every kg N ha^{-1} applied, in 6 of the 10 site-years. Soil-applied S also increased canola yields by 3–31% in 7 of the 10 site-years, but had no effect on yield components. While there was no change in yield from soil-applied B, the foliar B application at early flowering increased yields up to 10%, indicating that canola plants absorb B efficiently through their leaves. In summary, canola yields were improved by fertilization with N (8 of 10 site-years), S (7 of 10 site-years) and B (4 of 10 site-years). Yield gains were also noted with split N-fertilizer application that involved sidedressing N between the rosette and early flowering stage. Following these fertilizer practices could improve the yield and quality of canola crop grown in rainfed humid regions similar to those in eastern Canada.

Jaiswal *et al.* (2015) conducted an experiment at Mirzapur, Uttar Pradesh and found that the significant increment in seed and stover yield was noticed with increasing levels of S and B application and the seed yield was recorded maximum with application of RDF + 40 kg S/ha + 2 kg B/ha. The percent increase in seed yield was 34% than RDF (90, 60 and 40 kg/ha of N, P_2O_5, K_2O).

Mallick and Raj (2015) reported that successive increase in P, S and B levels increased yield attributes and seed yield of yellow sarson crop. Application of boron @ 1 kg B ha^{-1} also resulted into a significant increase in different growth attributes like plant height, dry matter accumulation, LAI and CGR over control. Application of B (1 kg ha^{-1}) had also resulted marked increase in siliquae $plant^{-1}$ and seeds $siliqua^{-1}$ compared with the control.

Increasing levels of S and B applications significantly increased seed and stover yield of mustard up to 40 kg S/ha and 2.0 kg B/ha. However, yield reduction was noticed with advancement of B application from 2 kg/ha to 3 kg/ha at Bichpuri, Agra (Singh *et al.* 2017 b).

Singh and Singh (2016) conducted a field experiment to study the response of mustard to different levels of sulphur and boron on yield and quality and they reported that number of siliquae plant^{-1}, no. of seeds siliqua^{-1}, test weight, seed yield and stover yield increased with increasing level of sulphur and boron.

Longkumer *et al* (2017) A field experiment was conducted to evaluate the effect of S and B application on growth, yield, and quality of soybean, and to find out their optimum doses for the best crop performance in acidic soils of northeast India. The treatments comprised four levels of S (0, 20, 40, and 60 kg/ha) and four levels of B (0, 0.5, 1.0, and 1.5 kg/ha) in factorial combination.In general, S40 + B1.5 also resulted in the highest nutrient nitrogen, phosphorus, potassium sulfur, and boron (NPKSB) uptake by soybean. Based on these results, we recommend the conjunctive use of 40 kg S and 1.5 kg B/ha for the best yield and quality of soybean on acidic soils of northeast India and other regions with similar soil.

Azam *et al.* (2017) studied the response of mustard *(Brassica rapa* L.) crop to varying levels of S - 0, 10, 20 and 30 kg/ha and B - 0, 1, 2 and 3 kg/ha in terms of yield and yield attributes. They reported that the highest seed yield was obtained under the treatment combination of S_2B_3 (20 kg S/ha + 3 kg B/ha), which was statistically at par with S_3B_2, S_3B_0 and S_3B_3, while significantly higher than other treatment combinations at Dhaka in Bangladesh.

Muthanna *et al* (2017) carried out an investigation to study the effect of boron and sulphur growth and yield of potato during the month of October in 2015- 16 and 2016-17. recommended dose of fertilizers (RDF) including 3 doses of boron (1 kg, 2 kg and 3 kg); 2 doses of sulphur (30 kg and 40 kg) and their combinations (1 kg boron + 30 kg sulphur, 2 kg boron + 30 kg sulphur, 3 kg boron + 30 kg sulphur, 1 kg boron + 40 kg sulphur, 2 kg boron + 40 kg sulphur and 3 kg boron + 40 kg sulphur) were applied. The study indicated that plant morphology and yield of potato plant were significantly influenced by boron and sulphur application. The maximum plant height and yield of marketable tubers (17.99 t ha-1 and 27.00 t ha-1) were recorded in the plants treated with RDF + 2 kg B + 40 kg S during both year of investigation. RDF + 2 kg B + 40 kg S was also found statistically at par with the maximum values under characters viz., number of sprouts per tuber, stem diameter and number of marketable tubers.

Verma and Dawson (2018) conducted a field experiment during the *rabi* season at Allahabad (U.P.) to evaluate the effect of sowing methods and levels of sulphur and boron on yield and economics of mustard *(Brassica compestris* L.) cv. Peela Sona. Results showed that the higher no. of siliquae plant^{-1}, number of seeds siliqua^{-1}, 1000-seed weight, seed yield (1740 kg ha^{-1}) and harvest index (41.90%) significantly increased the increasing levels of sulphur up to 30 kg ha^{-1} with boron 2 kg ha^{-1}.

Sharma *et al.*, (2020) conducted a field experiment during 2017-18 to evaluate the effect of boron and sulphur on growth and yield attributes of mustard. They observed that highest plant height, number of branches plant^{-1}, dry matter accumulation, number of siliqua plant^{-1}, number of seeds siliqua^{-1}, grain yield, stover yield and biological yield were maximum in the treatment of T_8- 100% RDF+ 2 kg B ha^{-1} + 45 kg S ha^{-1} and also significantly at par with T_9- 100% RDF + 3 kg B ha^{-1} +45 kg S ha^{-1}, T_6- 100% RDF + 2 kg B ha^{-1} + 30 kg S ha^{-1}, T_7- 100% RDF + 3 kg B ha^{-1} +30 kg S ha^{-1}.

At Mymensingh, Awal *et al.*, (2020) assessed the effect of agronomic biofortification of sulphur and boron on the growth and yield of mustard *(Brassica* *campestris* L.). They found that combined application of 40 kg S ha^{-1} along with 1 kg B ha^{-1} produced the maximum plant height, number of branches and leaves $plant^{-1}$, dry matter accumulation and yield attributes and yield of mustard.

Chapter 3

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

3.1 Location

The Experiment was conducted at the research farm of Sher-e-Bangla Agricultural University (SAU), Dhaka during the period from November, 2019 to February,2020 to study the effect of boron and sulfur fertilization on yield and yield attributes of mustard.

3.2 Site selection

The experimental site was located at $90^{o}22$ E longitude and 23^{o} 41 N latitude at an altitude of 8.6 meters above the sea level. The land was situatedat 28 Agro ecological zone (AEZ-28) of “Madhupur Tract”. It was deep red brown terrace soil and belongs to “Nodda” cultivated series.

3.3 Soil

Soil samples from 0-15 cm depths were collected from experimental site. The collected soil sample was mainly sandy soil to silty soil and loamy soil in texture. The analyses of soil were done by Soil Resources and Development Institute (SRDI), Dhaka. The physio-chemical properties of the soil are presented in Appendix I.

3.4 Climate and weather

The experiment area under the sub-tropical climate that is characterized by high temperature, high humidity and heavy rainfall with occasional gusty winds in Kharif-1 season (October-February) and rainfall associated with moderately temperature during the kharif-1 season (October-February). The monthly average air temperature, relative humidity and total rainfall during the study period (October-February) is shown in Appendix II.

3.5 Planting materials

The variety BARI Sarisha-14 (B. campestris) was used as plating materials in this experiment. The high yielding variety of mustard developed by Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.6 Seed collection

The seeds of mustard variety were collected from the Oilseed Centre, Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh. Before sowing seed, the seeds were tested for germination in the laboratory and the percentage of germination was found over 90% for the variety of mustard.

3.7 Experimental treatments

The experiment had 9 treatments of different boron and sulfur management of mustard. The treatments were as follows –

- $T_0 = B_0S_0$
- T_1 = 1 Kg B ha^{-1}
- T_2 = 2 Kg ha^{-1} B
- T_3 = 20 Kg ha^{-1} S
- T_4 = 40 Kg ha^{-1} S
- T_5 = 1 Kg ha^{-1} B + 20 Kg ha^{-1} S
- T_6 = 1 Kg ha^{-1} B + 40 Kg ha^{-1} S
- T_7 = 2 Kg ha^{-1} B + 20 Kg ha^{-1} S
- T_8 = 2 Kg ha^{-1} B + 40 Kg ha^{-1} S

3.8 Experimental Design and Layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The experimental field was divided into three blocks each of which represents a replication. Each block was divided into 9 plots in which treatments were distributed randomly. The distance maintained between two plots was 0.5m and between blocks was 1 m. The plot size was 2.5 m x 1.5 m. The layout of the experiment is shown in Appendix III.

3.9 Details of the field operations

The cultural operations that were carried out during the experiment are presented below:

3.9.1 Land preparation

The land was first ploughed by disc plough. It was then harrowed again and bring the soil in a better tilth condition. The clods of the land were hammered to make the soil into small pieces. Weeds, stubbles and crop residues were cleaned from the land. Finally ploughed thoroughly with a power tiller and then laddering was done to obtain a desirable tilth and land preparation was finally done.

3.9.2 Fertilizer application

The land was fertilized uniformly according to fertilizer dose. One third of the urea and full doses of other fertilizers were applied at the time of final land preparation. The remaining urea was top dressed into two splits at 20 and 30 days after sowing (DAS). Urea, triple super phosphate (TSP), muriate of potash (MP), gypsum, zinc oxide and boric acid were used as source of nitrogen, phosphorus, potassium, sulfur, zinc and boron respectively. The rate of N, P_2O_5, K_2O and Zn was 115-82-51-7.8 kg ha^{-1}respectively (BARI, 2002). Sulfur and Boron fertilizers were applied to the plot as per treatment in the form of gypsum (18% S) and Boric Powder.

3.9.3 Germination test

Germination test was completed before sowing the seeds in the experimental field. Petridishes were used for germination test. Three layers of filter paper were placed on petridishes and the filter papers were soft with water. Seeds were distributed randomly in four petridishes. Each petridish contained 25 seeds. Data on emergence were collected on percentage basis by using the following formula:

$Germination$ (%) of the crop =

$(Number of seed germinated / Number of seeds taken for germination) \times 100$

3.9.4 Seed sowing

Seeds were sown @ 7 kg /ha by hand as uniform as possible in the 30 cm apart lines. A strip of the same crop was established around the experimental field as border crop. Plant population was kept about 200 per plot. After sowing the mustard seeds were covered with soil and slightly pressed by laddering.

3.10 Intercultural operations

3.10.1 Thinning

Emergence of mustard seedling was completed within 25 days after sowing. The seedlings were thinned out two times during the study period where one healthy plant was allowed for grow in hill^{-1}. First thinning was done after 15 days of sowing which was done to remove lineless and unhealthy seedlings. The second thinning was done 10 days after first thinning.

3.10.2 Gap filling

Seedlings were transferred to fill in the gaps where seeds failed to germinate. The gaps were filled in within two weeks after germination of seeds.

3.10.3 Weeding

Weeds were controlled through two weedings at 15 and 25 days after sowing (DAS). Demarcation boundaries and drainage channels were also kept weed free.

3.10.4 Irrigation

Irrigation was done at three times. The first irrigation was given in the field at 25 days after sowing (DAS) through different irrigation channel. The second irrigation was given at the stage of maximum flowering (35DAS). The final irrigation was given at the stage of seed formation (50 DAS).

3.10.5 Pest management

The crop was infested with aphids (*Lipaphis erysimi*) at the time of siliqua filling. The insects were controlled successfully by spraying Malathion 50 EC @ 2ml /L water. The insecticide was sprayed thrice. The crop was kept under constant observations from sowing to harvesting.

3.11 Harvesting and threshing

The crop was harvested plot wise when 90% siliquae were matured. After collecting sample plants, harvesting was done. The harvested plants were tied into bundles and carried to the threshing floor. The plants were sun dried by spreading the bundles on the threshing floor. The seeds were separated from the stover by beating the bundles with bamboo sticks. Per plot yields of seed and straw were recorded after drying the plants in the sun followed by threshing and cleaning. At harvest, seed yield was recorded plot wise andexpressed on hectare basis. Oven dried seeds were put in desiccators for chemical analysis.

3.12 Recording of data

The data on crop characters were recorded at harvest. The yield and yield contributing characters were recorded from the selected plants and from harvest area in each plot.

3.13 Collection of experimental data

The following parameters were considered for data collection:

- Plant height at 30, 45, 60 DAS
- No. of leaves per plant at 30 and 45 DAS
- No. of branch per plant
- SPAD value of leaf
- Siliqua per plant
- Seed per siliqua
- 1000 seed weight
- Seed yield
- Stover yield

- Biological yield
- Harvest index

3.14 Procedure of data collection

- **Plant height**

The plant height was measured at 30, 45 and 60 DAS and at harvest with a meter scale from the ground level to the top of the plants and the mean height was expressed in cm. Plant height was measured from randomly selected 10 plants of each plot.

- **Number of leaves per plant**

The number of leaves per plant was counted at 30 and 45 DAS from selected plants. The average number of leaves per plant was determined and recorded. Randomly selected 10 plants of each plot were considered for measuring the number of leaves per plant.

- **Number of branches per plant**

The number of branches per plant was counted at harvest from selected plants. The average number of branches per plant was determined and recorded. Ten plants were selected randomly from each plot for the calculation of the number of branches per plant.

- **Measuring SPAD Value**

For measuring chlorophyll content, we used spectrophotometry method. SPAD meter reading of fresh leaves was recorded to compare relative chlorophyll content of leaves. 5 reading were taken from leaves of each sample plant avoiding the mid-rib region carefully and average value was presented as SPAD value of leaves. Higher SPAD value was considered as higher total chlorophyll (pigments) content of leaf.

- **Number of siliqua per plant**

Numbers of total siliqua of selected plants from each plot were counted and the mean numbers were expressed as per plant basis. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot.

- **Number of seeds per siliqua**

The number of seeds per siliqua was recorded from randomly selected 10 siliqua at the time of harvest. Data were recorded as the average and express in seeds per siliqua.

- **1000 seed weight**

One thousand cleaned, dried seeds of mustard were counted from each harvest sample and weighed by using a digital electronic balance and weight was expressed in gram (g).

- **Seed yield**

The seeds yield of each plot were converted into yield per hectare and express in seed yield of t/ha.

- **Stover yield**

The stover yield of each plot were converted into yield per hectare and express in stover yield of t/ha.

- **Biological yield**

Grain yield and stover yield together were regarded as biological yield of mustard. The biological yield was calculated with the following formula:

Biological yield (t/ha) = Grain yield + Stover yield

- **Harvest index**

Harvest index was calculated from the seed and stover yield of mustard and expressed in percentage.

$$HI = \frac{\text{Seed yield}}{\text{Biological yield (seed + stover yield)}} \times 100$$

3.15 Organic matter content

Organic carbon of the soil was measured by wet oxidation method of Black (1965). The under laying principal was used to oxidize the organic matter with an exces of 1N $K_2Cr_2O_7$ solution with 1N $FeSO_4$. To obtain in organic matter content, the amount of organic carbon was multiplied by the van Bemmelen factor 1.73. The result was expressed in percentage (Page et al., 1982).

3.16 Statistical analysis

The data obtained from experiment on various parameters were statistically analyzed in MSTAT–C computer program. The mean values for all the parameters of the experiment were calculated and the analyses of variance for the characters were accomplished by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

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Chapter 4

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

This study was conducted to know the response of boron and sulfur fertilization on yield and yield attributes of mustard. The results have been presented and discussed, and possible explanations have been given under the following headings:

4.1 Effect of Sulfur and Boron on plant height

Single and combined effect of Sulfur and Boron on mustard plant height is shown in Table 1. Mustard plant height at 30, 45 and 60 DAS was significantly affected because of the effect of Sulfur and Boron (Appendix IV). The highest plant height at 30, 45 and 60 DAS (52.37, 97.40 and 113.0cm) was obtained from the treatment of T_4, whereas the lowest height at 30, 45 and 60 DAS (42.60, 76.33 and 91.50 cm) was found from control treatment T_0. Plant height obtained in this study was higher than the results obtained by Mohiuddin (2007) who reported the tallest mustard plant (93.0cm) from the treatment combination N_2S_3comprising of 80 kg N/ha F 24 kg S/ha, while the shortest plant (72.0cm) was recorded from N_0S_0 i.e. no nitrogen no Sulphur. On the other hand, Islam (2003) reported the highest plant height (74.23cm) from the treatment of 30kg S + 20kg Mg ha^{-1}, whereas the lowest height (56.67cm) was obtained from control treatment. Supported result was also observed from the findings of Muthanna *et al* (2017) and Mallick and Raj (2015).

Table 1. Effect of Sulfur and Boron on plant height of mustard

Treatment	Plant height (cm)		
	30DAS	45DAS	60DAS
T_0	42.60 d	76.33 e	91.50 e
T_1	42.67 d	83.33 d	98.73 d
T_2	45.13 c	85.53 d	101.2 cd
T_3	45.07 c	84.53 d	99.47 d
T_4	44.27 c	88.37 c	102.2 c
T_5	52.37 a	97.40 a	113.0 a
T_6	47.40 b	90.60 bc	105.0 b
T_7	47.48 b	91.30 b	105.7 b
T_8	47.07 b	90.33 bc	103.8 bc
$LSD_{5\%}$	1.350	2.436	2.619
CV (%)	5.07	4.82	4.44

4.2 Effect of Sulfur and Boron on no. of leaves per plant of mustard

Leaf number per plant was significantly affected by sulfur and boron single and combined doses which is shown in Table 2 and Appendix IV. At 30 DAS, maximum leaf number (16.07) was recorded at the treatmentT_5. Minimum leaf number (11.90) was observed at the combination of 0 kg ha^{-1} sulfur dose and 0 kg ha^{-1} boron dose or at control (T_0). At 45 DAS maximum leaf number (20.87) was also recorded from the treatment T_5. The Minimum leaf number (14.53) was observed at the control treatment (T_0). The result obtained from the present study was similar with the findings of Awal *et al.*, (2020) and Ma *et al.*, (2015).

Table 2. Effect of Sulfur and Boron on plant height and no. of leaves per plant of mustard

Treatment	No. of leaves per plant	
	30DAS	45DAS
T_0	11.93 d	14.53 e
T_1	14.67 b	16.80 c
T_2	13.93 c	15.40 d
T_3	14.93 b	15.73 d
T_4	14.13 c	17.40 b
T_5	16.07 a	20.87 a
T_6	13.87 c	17.57 b
T_7	14.27 c	17.57 b
T_8	13.93 c	17.67 b
$LSD_{5\%}$	0.3888	0.5186
CV (%)	4.75	5.27

4.3 Effect of Sulfur and Boron on number of branches per plant

Sulfur and Boron has significantly affected the number of branches plant^{-1} (Appendix V and Figure 1). However, the highestnumber of branch per plant (10.07) was obtained from T_5 (1 Kg B ha^{-1} + 20 Kg S ha^{-1}) and lowest number of brunches (6.93) was obtained from T_0 (B_0S_0). Kanpara *et al.* (1992) found the opposite result. They observed that the growth character of mustard such as primary and secondary branches plant^{-1} was significantly increased up to 100 kg S ha^{-1}.

In a previous study, Mohiuddin (2007) reported significant combined effect between nitrogen and Sulphur for the number of branches per plant. He reported the maximum number of branches per plant (8.10) was observed from the treatment combination N_2S_3 having 80 kg N/ha 24 kg S/ha.

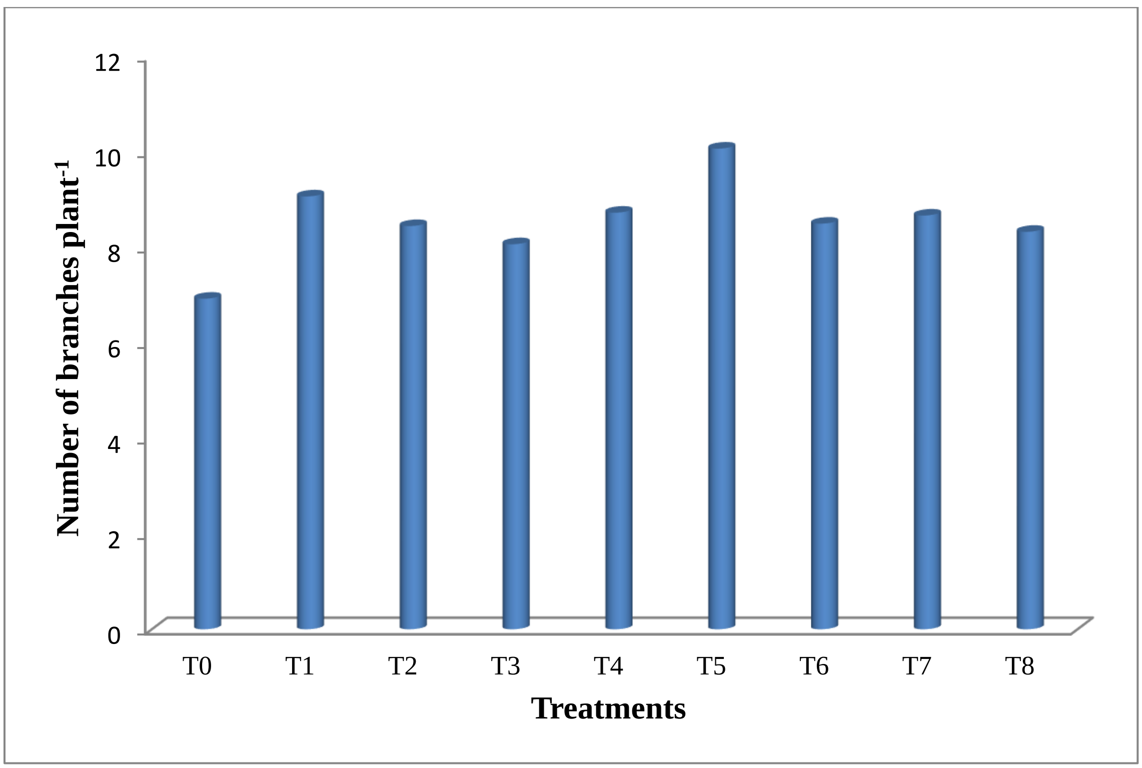

Fig. 1: Effect of Sulfur and Boron on number of branches per plant

4.4 Effect of Sulfur and Boron on SPAD value of leaf

SPAD value of leaf was significantly affected by the interaction and single doses of sulfur and boron throughout the mustard lifecycle which is shown in Appendix V and Figure 2. The maximum SPAD value of leaf (52.63) was observed from T_5 (1 Kg B ha^{-1} + 20 Kg S ha^{-1}),whereas the lowest SPAD value of leaf (42.17) was obtained from T_0 (B_0S_0).

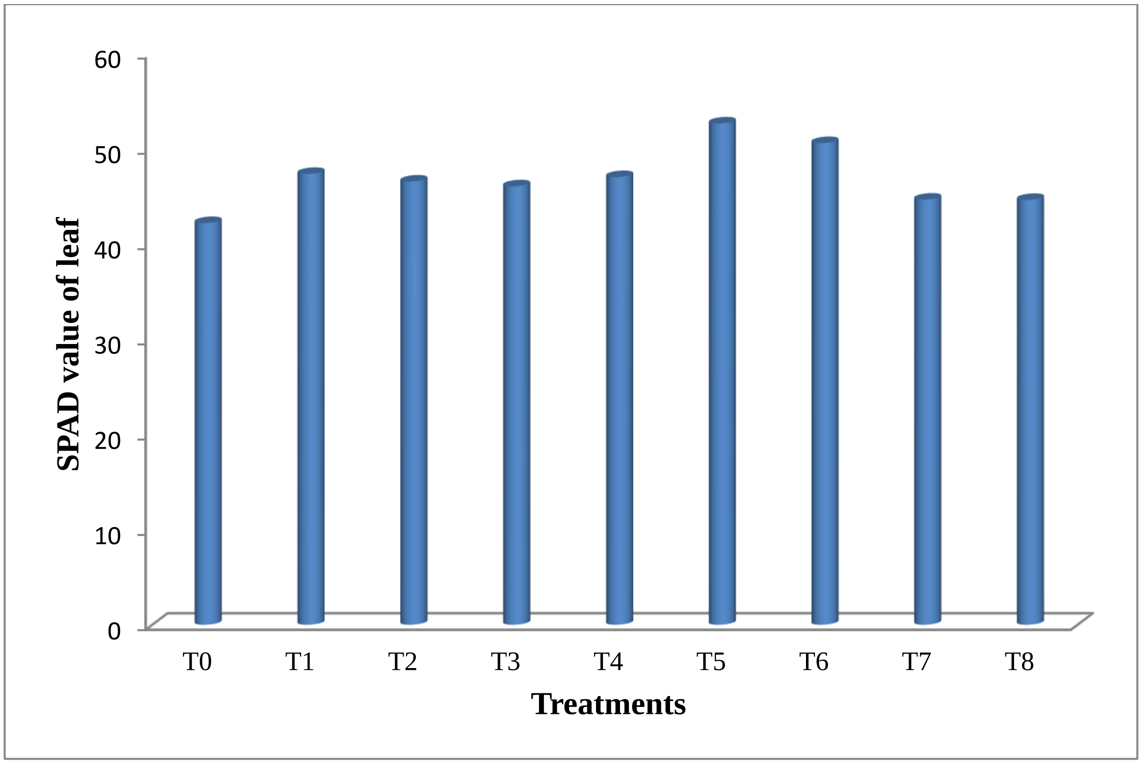

Fig. 2: Effect of Sulfur and Boron on SPAD value of leaf

4.5 Number of siliquae plant^{-1}

Number of siliquae on a plant significantly influenced by Sulfur and Boron (Appendix V). The highest number of siliquae (137) was observed from T_5 (1 Kg B ha^{-1} + 20 Kg S ha^{-1}). whereas the lowest number of siliquae (74.07) was resulted for T_0 (0 Kg B ha^{-1} + 0 Kg S ha^{-1}). Figure 3 also shows that siliquae number plant^{-1} was largely influenced by Boron and Sulfur when applied over control.

Similar trend regarding siliquae formation/plant was observed by Gupta *et al.* (1980) who reported that application of Boron increased siliqua formation of mustard.A significant combined effect between nitrogen and Sulphur for number of siliqua per plant was also observed by Mohiuddin (2007). The maximum number of siliqua per plant (165) was recorded from the ifeatment combination N_2S_3 (80 kg N/ha + 24 kg S/ha).

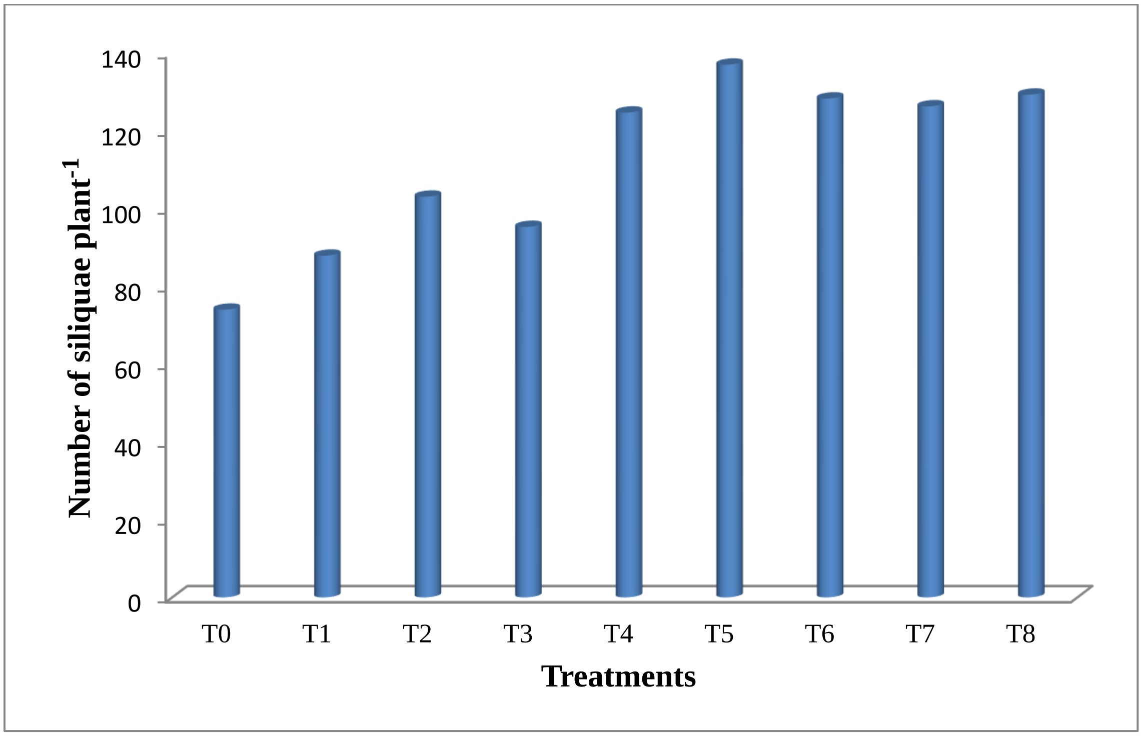

Fig. 3: Effect of Sulfur and Boron on Number of siliquae plant^{-1}

4.6 Number of seed siliqua^{-1}

Number of seeds siliqua^{-1} was significantly affected by the interaction and single doses of sulfur and boron which is shown at Appendix V and Figure 4. The maximum number of seeds siliqua^{-1} (34.17) was recorded at the combination of 1 Kg B ha^{-1} + 20 Kg S ha^{-1} (T_5). The minimum number of seeds siliqua^{-1} (26.27) was observed at the combination of0 Kg B ha^{-1} + 0 Kg S ha^{-1} (T_0).

Number of seed per capsule in this study was quite lower than the value (24.7no) reported by Mohiuddin. (2007) for the treatment combination N_2S_3 comprising of 80 kg N/ha + 24 kg S/ha. On the other hand. Islam (2003) reported the highest seeds per pod (17.6nos) from the treatment of 30kg S + 20kg Mg ha^{-1}, whereas lowest height (12.42nos) was found in control. Rahman *et al.* (1978) reported that the application of sulfur was favourable for the production of more seeds siliqua^{-1}. Muthanna *et al* (2017) and Verma and Dawson (2018) also found similar result with the present study.

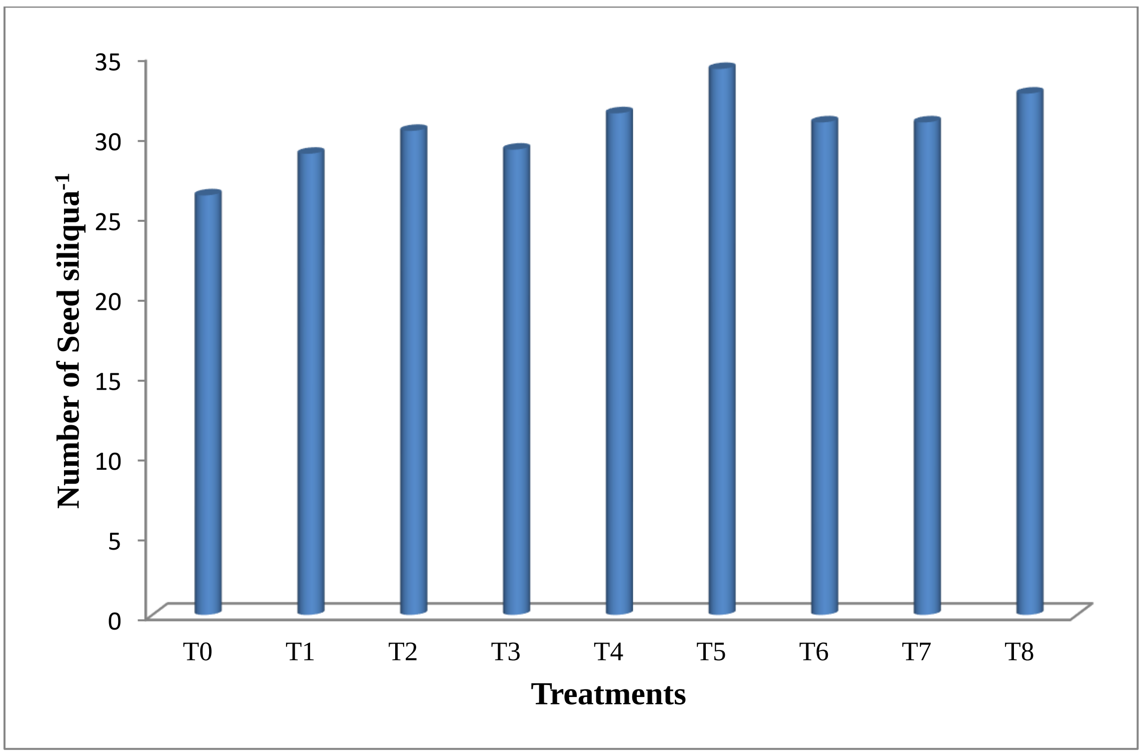

Fig. 4: Effect of Sulfur and Boron on Number ofseed siliqua^{-1}

4.7 1000 seed weight (g)

Sulfur and Boron showed statistically significant differences for 1000 seed weight of mustard under the present trial (Appendix VI and Figure 5).The highest weight of 1000 of seeds (3.90 g) was recorded from treatment T_5 (1 Kg B ha^{-1} + 20 Kg S ha^{-1}) and the lowest weight of 1000 of seeds (3.00 g) was recorded from T_0 treatment (0 Kg B ha^{-1} + 0 Kg S ha^{-1}).

Mohiuddin, (2007) who observed the highest weight of 1000 seed (2.86g) from the treatment combination N2S3 comprising of 80 kg N/ha + 24 kg S/ha and the lowest (1.60g) was recorded from N_0S_0 where no nitrogen and Sulphur were applied. At previous study. Islam (2003) reported the highest 1000-seed weight (2.75g) from the treatment of 30kg S + 20kg Mg ha^{-1}, whereas lowest 1000-seed weight (1.57g) was obtained from the treatment of 45kg S + 30kg Mg ha^{-1}.

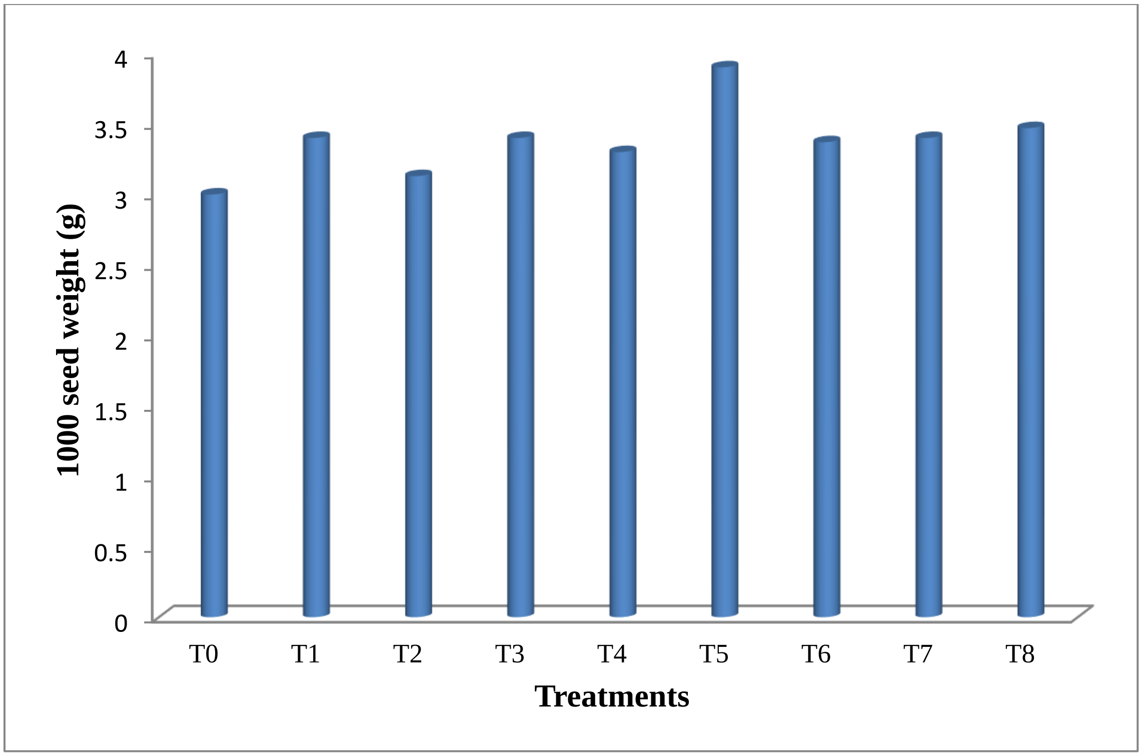

Fig. 5: Effect of Sulfur and Boron on 1000 seed weight

4.8 Seed yield (t/ha)

Significant difference was observed among single and combined treatments of Sulfur and Boron in respect of grain yield (Appendix VI and Figure 6). Increasing rate of grain yield was not same with all single and combined treatments of higher Sulfur and Boron level. The highest grain yield (1.64 tha^{-1}) was obtained from T_5 treatment (1Kg B ha^{-1} + 20 Kg S ha^{-1}) and the lowest grain yield (0.91 tha^{-1}) was found with control (B_0S_0). Karthikeyan and Shukla (2011) reported increased mustard seed yield with the combination of higher sulfur and Boron level and highest yield (20.6 g pod^{-1}) with 560132 (60 g S kg^{-1} and 2 mg 13 kg^{-1}) treatment.

Lower grain yield (kg/ha) of mustard was revealed by Mohiuddin (2007) who found the highest yield (1738 kg/ha) from the treatment combination N_2S_3 comprising of 80 kg N/ha + 24 kg S/ha and the lowest (850 kg/ha) from N_0S_0 where no nitrogen and Sulphur was applied. However, quite lower yield of mustard was also observed by Islam (2003) who reported the highest seed yield (984.00 $kgha^{-1}$) from the treatment of 30kg S + 20kg Mg ha^{-1}, whereas lowest seed yield (517.33 $kgha^{-1}$) was obtained from the control. Supported result was also found from the findings of Awal *et al.*, (2020), Sharma *et al.*, (2020), Verma and Dawson (2018) and Muthanna *et al* (2017).

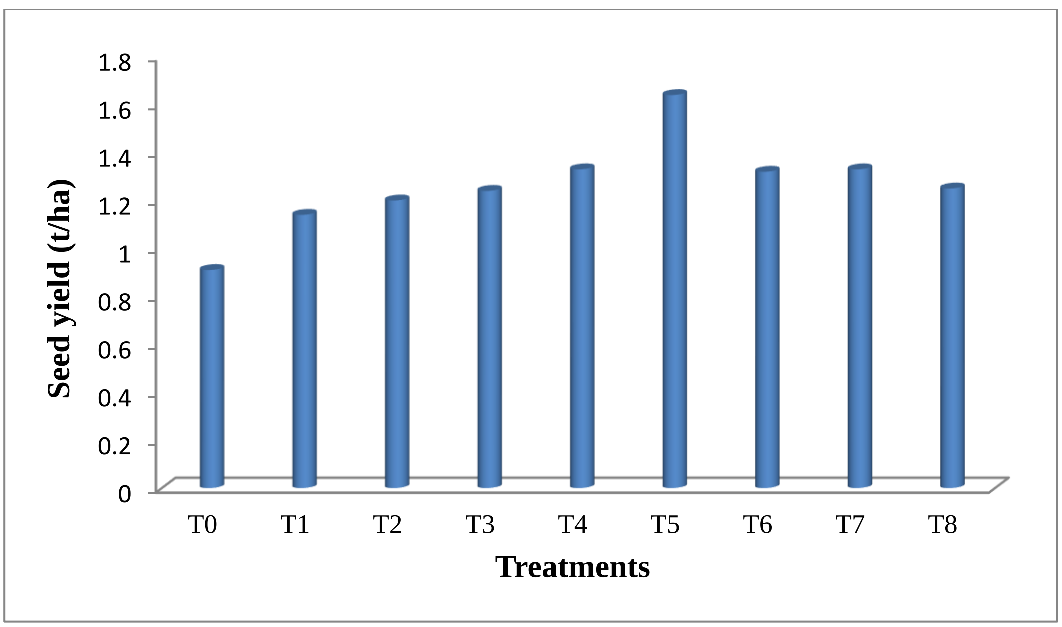

Fig. 6: Effect of Sulfur and Boron on Seed yield

4.9 Stover yield (t/ha)

Stover yield was significantly affected by sulfur and boron doses which was shown at Figure 7 (Appendix VI). The highest stover yield (3.97 t ha^{-1}) was obtained from T_5 treatment. The lowest stover yield (3.10 t ha^{-1}) was found from control treatment. Results also revealed that the effect of Sulfur on stover yield was more than the Boron level. Stover yield in this study was much higher than the result of Mohiuddin (2007) who reported the highest shoot yield (1748/ha) from the treatment combination N_2S_3 comprising of 80 kg N/ha + 24 kg S/ha and the lowest (918 kg/ha) from N_0S_0 where no nitrogen and Sulphur was applied. This variation may be occurred due to harvesting method of mustard.

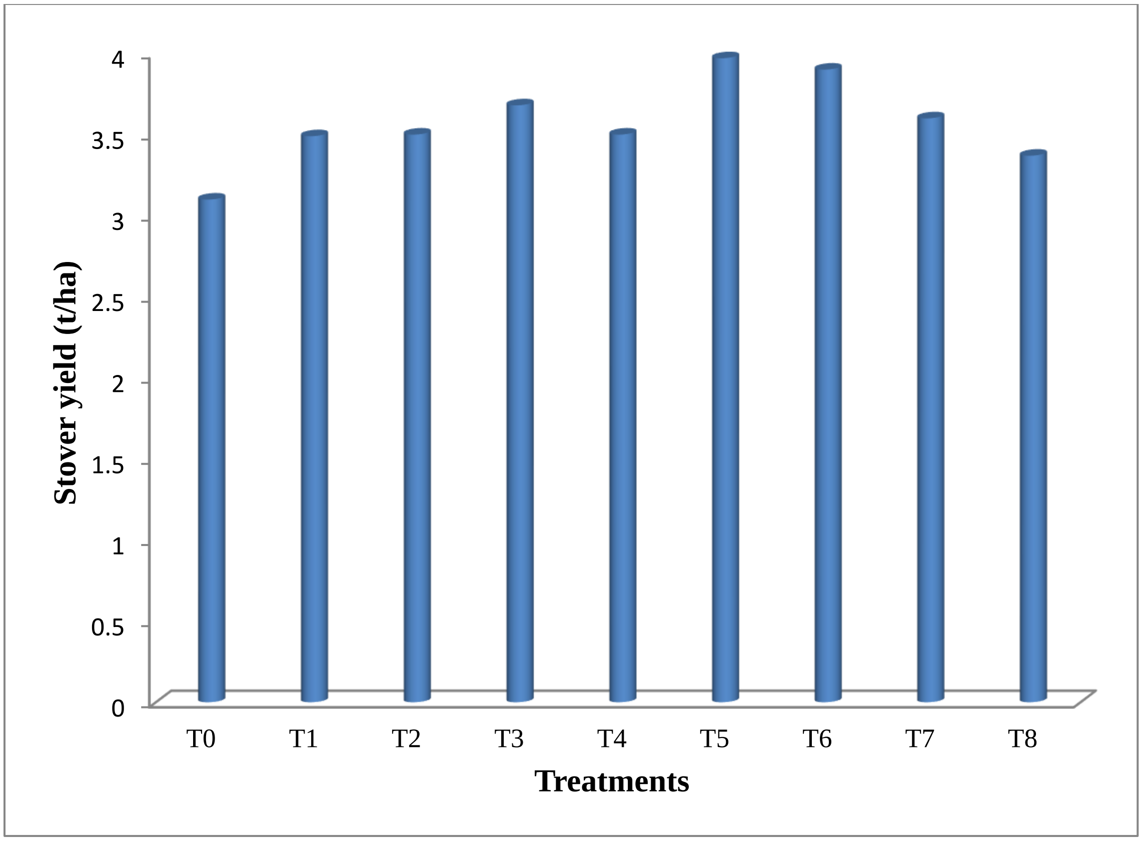

Fig. 7: Effect of Sulfur and Boron on Stover yield

4.10 Biological yield (t/ha)

Biological yield was significantly affected by sulfur and boron doses (Appendix VI and Figure 8). The highest biological yield (5.62 t ha^{-1}) was obtained at the combination of 1 Kg B ha^{-1} + 20 Kg S ha^{-1} (T_5). The lowest biological yield (4.01 t ha^{-1}) was found at the combination of 0 kg ha^{-1} sulfur dose and 0 kg ha^{-1} boron dose (B_0S_0).

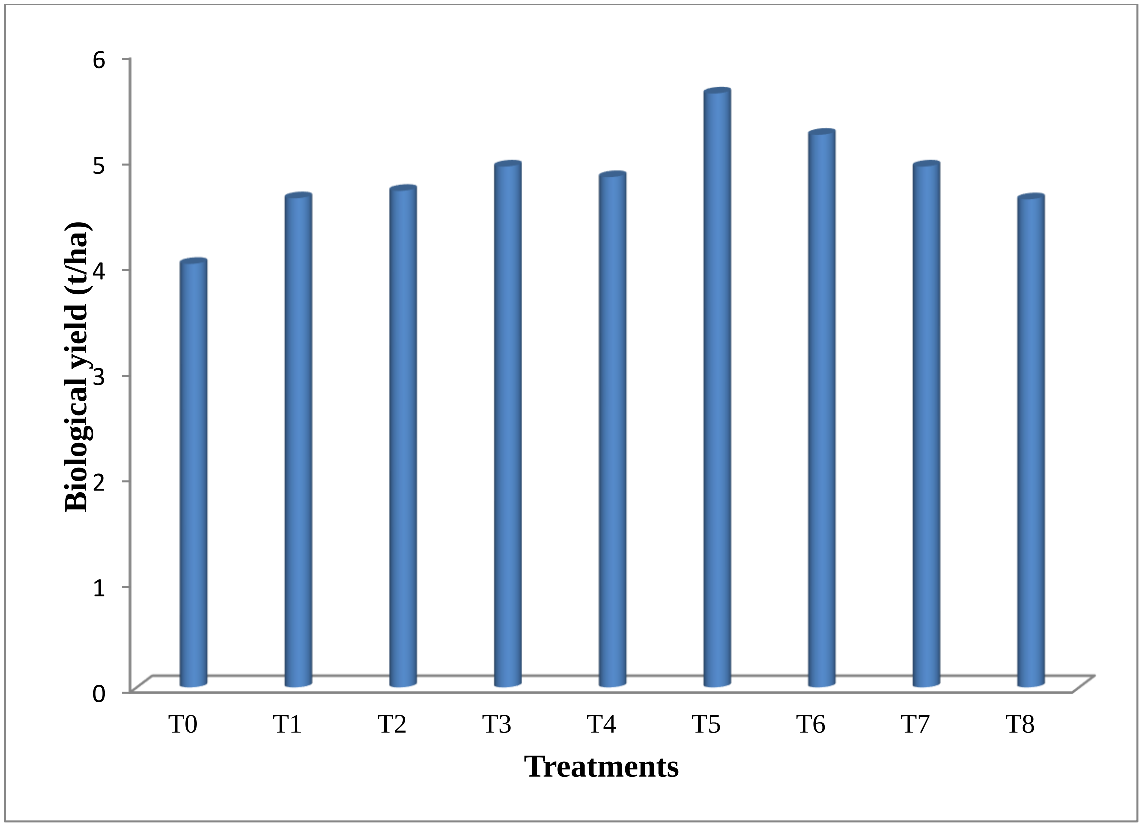

Fig. 8: Effect of Sulfur and Boron on Biological yield

4.11 Harvest index (%)

Harvest index was positively influenced as a single and combined effect of different levels of Sulfur and Boron (Appendix VI and Figure 9). Significant effect of single combined dose of Sulfur and Boron on harvesting index was revealed in this research work (Appendix VI). The combined dose of 1 Kg B ha^{-1} + 20 Kg S $ha^{-1}$was found regarding highest harvest index (29.20%) of mustard in this research (Figure 9). The lowest harvest index (22.73%) was found from the treatment of T_0 (0kg S ha^{-1} and 0 kg B ha^{-1}). If combined dose above the optimum dose is applied, there would be risk of lower harvesting index.

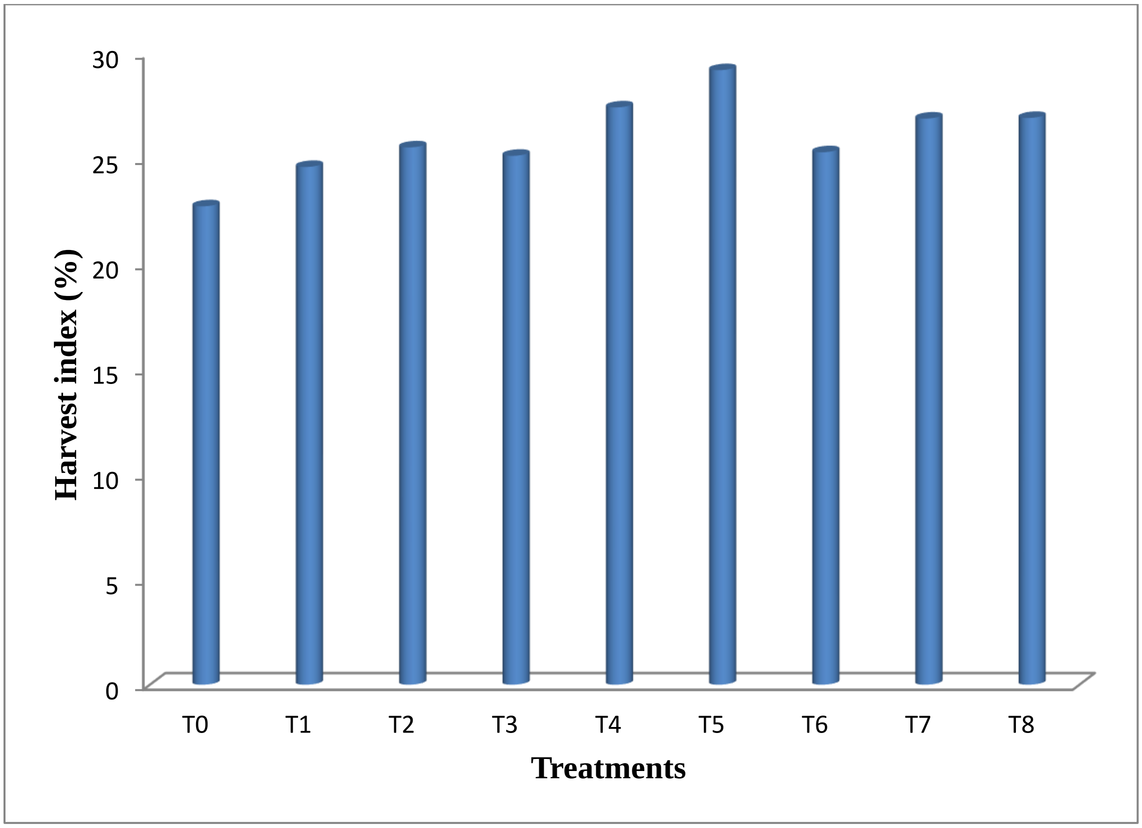

Fig. 9: Effect of Sulfur and Boron on Harvest index

Chapter 5

SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was carried out at the research field of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka during the period from November, 2019 to February, 2020 to investigate the response of boron and sulfur fertilization on yield and yield attributes of mustard.

The experiment was laid out in single factors Randomized Complete Block Design (RCBD) with three replications. The size of unit plot was 2.5 m x 1.5 m and total number of plots was 27. There were 9 treatments in the experiment. The treatments wereT_0 = B_0S_0, T_1 = 1 Kg B ha^{-1}, T_2 = 2 Kg B ha^{-1}, T_3 = 20 Kg S ha^{-1}, T_4 = 40 Kg S ha^{-1}, T_5 = 1 Kg B ha^{-1} + 20 Kg S ha^{-1}, T_6 = 1 Kg B ha^{-1} + 40 Kg S ha^{-1}, T_7 = 2 Kg B ha^{-1} + 20 Kg S ha^{-1} and T_8 = 2 Kg B ha^{-1} + 40 Kg S ha^{-1}

The hole amount of TSP, MP were applied during the final preparation of experimental plot. Urea was applied in two equal installments as top dressing at tillering and panicle initiation stages.Sulfur and Boron fertilizers were applied to the plot as per treatment in the form of gypsum (18% S) and Boric Powder. Different intercultural operations such as gap filling, irrigation, drainage, weeding etc. were done as and when required in the mustard filed. The crop was harvested at full maturity and ten hills were randomly selected from each unit plot prior to harvest for recording different data on plant characters and yield components. Duncan's Multiple Range Test (DMRT) compared all the collected data with the help of MSTAT-C software.

Results revealed that main effect of Sulphur and Boron was significant in respect of studied parameters viz, plant height (cm) at 30, 45, 60 DAS, no. of leaves per plant at 30 and 45 DAS, no. of branch per plant, SPAD value of leaf, siliqua per plant, seed per siliqua, 1000 seed weight (g), seed yield (t/ha), stover yield (t/ha), biological yield (t/ha) and harvest index (%).

It was revealed that the effect of Sulfur and Boron were showed significant variation of all growth and yield parameter of mustard. The experimental findings revealed that, the highest plant height at 30, 45 and 60 DAS (52.37, 97.40 and 113.0 cm),maximum leaf number (16.07),highest number of branch per plant (10.07),maximum SPAD value of leaf (52.63),highest number of siliquae (137),maximum number of seeds siliqua^{-1} (34.17),highest weight of 1000 of seeds (3.90 g),highest grain yield (1.64 tha^{-1}),highest stover yield (3.97 t ha^{-1}),highest biological yield (5.62 t ha^{-1}) and highest harvest index (29.20%)were obtained from the combination of 1 Kg B ha^{-1} + 20 Kg S ha^{-1} (T_5).The lowest height at 30, 45 and 60 DAS (42.60, 76.33 and 91.50 cm),minimum leaf number (11.90),lowest number of brunches (6.93),lowest SPAD value of leaf (42.17),lowest number of siliquae (74.07),minimum number of seeds siliqua^{-1} (26.27),lowest weight of 1000 of seeds (3.00 g), lowest grain yield (0.91 tha^{-1}), lowest stover yield (3.10 t ha^{-1}), lowest biological yield (4.01 t ha^{-1}) and lowest harvest index (22.73%) were obtained from T_0 (B_0S_0).

From the findings of the present study, it may be concluded that Sulphur at the rate of 1 Kg B ha^{-1} + 20 Kg S ha^{-1} had significant and favorable effect for improving yield component and improving yield of mustard. Considering the results of the present experiment, further studies in the following areas are suggested:

- ❖ Studies of similar nature could be carried out in different Agro-ecological zones (AEZ of Bangladesh for the evaluation of zonal adaptability.
- ❖ Other varieties with different management practice might be included in further studies.

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APPENDICES

APPENDICES

Appendix-I. Physical and Chemical characteristics of initial soil (0-15cm depth) before seed sowing

A. Morphological characteristics of the experimental field (Source: Characteristics of experimental soil was analyzed at Soil Resources Development Institute; SRDI, Farmgate, Dhaka**)**

Morphological features	Characteristics
Location	Farm, SAU, Dhaka
AEZ (Agro Ecological Zone)	Modhupur tract (28)
Type of soil (general)	Shallow red brown terrace soil
Type of land	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	N/A

B. Physical properties of the initial soil (Source: SRDI**)**

Characteristics	Value
Practical size analysis	
Sand (%)	16
Silt (%)	56
Clay (%)	28
Silt + Clay (%)	84
Textural class	Silty clay loam
pH	5.56
Organic matter (%)	1.00

C. Chemical properties of the initial soil (Source: SRDI**)**

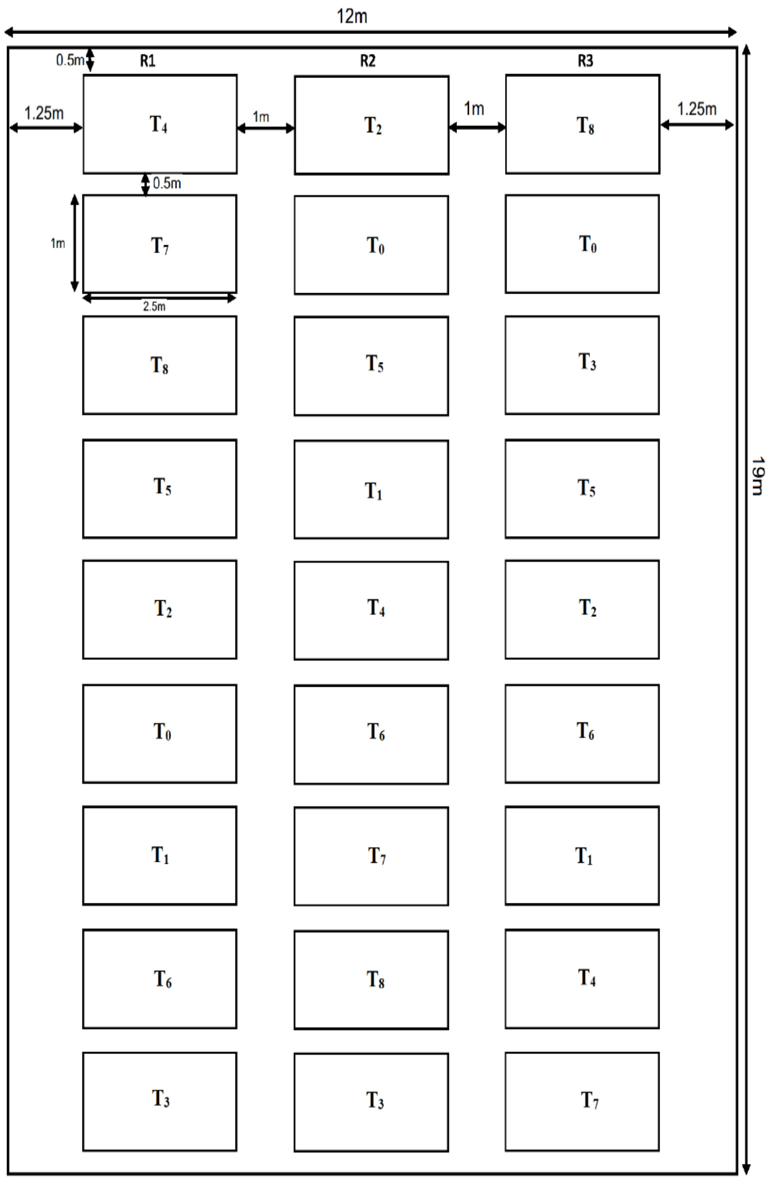
Characteristics	**Value**
Total N (%)	0.02%
P	53.64 µgm/gm
K	0.13 meq/100gm
S	9.40 µgm/gm
B	0.13 µgm/gm
Zn	0.94 µgm/gm
Cu	1.93 µgm/gm
Fe	240.9 µgm/gm
Mn	50.6 µgm/gm

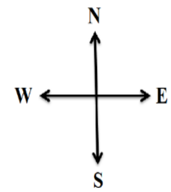
Appendix-II. Monthly Temperature, Rainfall and Relative humidity of the experiment site during the period from November 2019 to February 2020

Year	Month	Air Temperature (ºC)			Relative humidity (%)	Rainfall (mm)
		Maximum	Minimum	Mean		
2019	November	29.2	20.5	24.8	67.0	9.0
	December	26.4	17.0	21.7	60.0	9.0
2020	January	26.0	15.3	20.7	53.0	2.0
	February	29.8	17.4	23.6	45.0	10.0

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1207.

Appendix-III. Experimental layout





LEGEND:

Plot size: 19 m × 12m = 228 m^2

Treatments:

- $T_0 = B_0S_0$
- T_1 = 1 Kg B ha^{-1}
- T_2 = 2 Kg ha^{-1} B
- T_3 = 70 Kg ha^{-1} S
- T_4 = 140 Kg ha^{-1} S
- T_5 = 1 Kg ha^{-1} B + 70 Kg ha^{-1} S
- T_6 = 1 Kg ha^{-1} B + 140 Kg ha^{-1} S
- T_7 = 2 Kg ha^{-1} B + 70 Kg ha^{-1} S
- T_8 = 2 Kg ha^{-1} B + 140 Kg ha^{-1} S

Appendix IV. Means square values for plant height and no. of leaves per plant of mustard

Sources of variation	DF	Plant height (cm)			No. of leaves per plant	
		30DAS	45DAS	60DAS	30DAS	45DAS
Replication	2	0.734	2.065	8.108	3.246	1.714
Factor A	8	28.836*	107.084*	102.765*	3.615*	9.921*
Error	16	5.471	17.826	20.606	0.454	0.808

NS= Not Significant, *= Significant at 5% level of Probability, **= Significant at 1% level of Probability.

Appendix V. Means square values for branches per plant SPAD value of leaf, no. of pod per plant,siliqua per plant, seed per siliqua and 1000 seed weight of mustard

Sources of variation	DF	No. of branches per plant	SPAD value of leaf	Number of siliquae $plant^{-1}$	Number of Seed $siliqua^{-1}$
Replication	2	0.403	0.763	55.761	1.358
Factor A	8	2.069*	30.072*	1474.598*	15.571*
Error	16	0.227	2.704	23.773	1.877

NS= Not Significant, *= Significant at 5% level of Probability, **= Significant at 1% level of Probability.

Appendix VI. Means square values for seed yield, stover yield, biological yield (t/ha) and harvest index (%) of mustard

Sources of variation	DF	1000 seed weight (g)	Seed yield (t/ha)	Stover yield(t/ha)	Biological yield (t/ha)	Harvest index (%)
Replication	2	0.051	0.007	0.259	0.351	2.114
Factor A	8	0.184*	0.112*	0.213*	0.589*	10.522*
Error	16	0.032	0.004	0.003	0.013	0.634

NS= Not Significant, *= Significant at 5% level of Probability, **= Significant at 1% level of Probability